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(54) TITLE OF INVENTION

Ultrasonic Flaw Detecting Method of Pipe Welded Joint

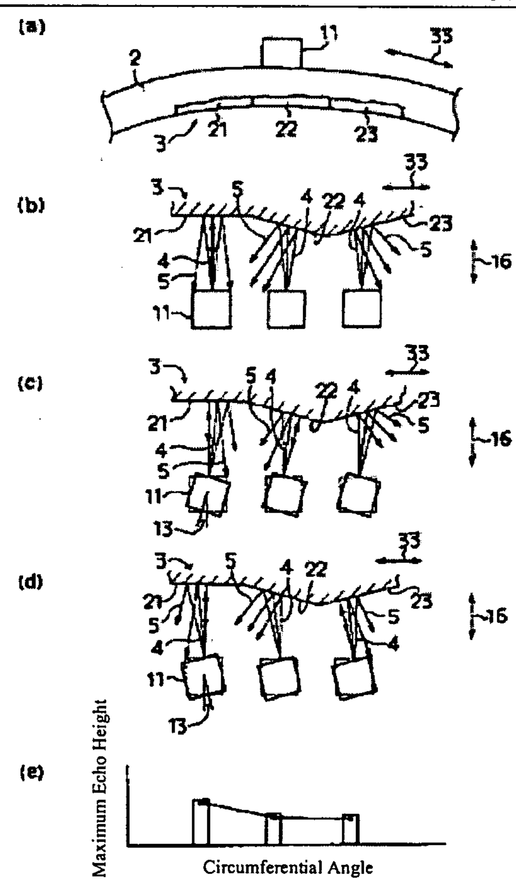
(57) ABSTRACT

PROBLEM TO BE SOLVED

To precisely measure a minute crack 3 generated on the inner surface of a pipe 2.

SOLUTION

A focusing ultrasonic probe 11 is positioned at a base position having a designated distance from a welded joint on the outer surface of a pipe 2 along the pipe axial direction 16, the ultrasonic probe 11 scans over the whole circumference while shifting position by a minute pitch of 1-5° in the circumferential direction 33, three kinds of reflected waves 5, namely, the reflected wave 5 obtained by making an ultrasonic wave 4 incident on the welded joint 12 from the pipe axial direction 16, the reflected wave 5 obtained by making the ultrasonic wave 4 incident on the welded joint 12 with an inclination of 5-15° from the pipe axial direction 16, and the reflected wave 5 obtained by making the ultrasonic wave 4 incident on the welded joint 12 with an inclination of -5° ~ -15° from the pipe axial direction 16, are measured, and the maximum value of the three reflected waves 5 from the same destination point is used to estimate the shape of a crack 3.



Scope of Patent Claims

Claim 1

An ultrasonic flaw detecting method for pipe weld seams which extend in the circumferential direction of a pipe where ultrasonic waves are made incident on the outside of the pipe, reflected waves from a crack are detected, and the crack measured while moving position in the circumferential direction along the weld seam, comprising

Determining the distance to a base point where an ultrasonic probe should be positioned with regards to a weld seam, based on the location where a weld seam proximal crack is predicted and the angle of incidence of the ultrasonic waves;

Positioning a focusing ultrasonic probe which has a narrow ultrasonic wave divergence angle at a base position having said distance in the axial direction of the pipe from the weld seam of the pipe outer surface;

Scanning the whole circumference while moving said focusing ultrasonic probe in the circumferential direction by minute pitches of 1° ~ 5°;

Measuring three types of reflected waves, namely the reflected wave obtained by making an ultrasonic wave incident on the welded joint from the pipe axial direction, the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of 5° ~ 15° from the pipe axial direction, and the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of -5° ~ -15° from the pipe axial direction; and

Using the maximum value at one destination point of said three types of reflected waves to estimate the shape of a crack.

Claim 2

An ultrasonic flaw detecting method for pipe weld seams which extend in the axial direction of a pipe where ultrasonic waves are made incident on the outside of the pipe, reflected waves from a crack are detected, and the crack measured while moving position in the axial direction along the weld seam, comprising

Determining the distance to a base point where an ultrasonic probe should be positioned with regards to a weld seam, based on the location where a weld seam proximal crack is predicted and the angle of incidence of the ultrasonic waves;

Positioning a focusing ultrasonic probe which has a narrow ultrasonic wave divergence angle at a base position having said distance in the circumferential direction of the pipe from the weld seam of the pipe outer surface;

Scanning the whole length of the weld seam while moving said focusing ultrasonic probe in the axial direction by designated pitches;

Measuring three types of reflected waves, namely the reflected wave obtained by making an ultrasonic wave incident on the welded joint from the pipe circumferential direction, the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of 5° ~ 15° from the pipe circumferential direction, and the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of -5° ~ -15° from the pipe circumferential direction; and

Using the maximum value at one destination point of said three types of reflected waves to estimate the shape of a crack.

Claim 3

The ultrasonic flaw detecting method for pipe weld seams as claimed in Claim 1 or Claim 2, wherein

The operations of said Claim 1 or Claim 2 are performed at a new base position 0.1 ~ 0.3 times the pipe thickness closer than said base position and at a new base position 0.1 ~ 0.3 times the pipe thickness farther than said base position;

If necessary the operations of said Claim 1 or Claim 2 are also performed at a new base position 0.4 ~ 0.6 times the pipe thickness closer than said base position and at a new base position 0.4 ~ 0.6 times the pipe thickness farther than said base position; and

The maximum values from the three types or five types of reflected waves obtained from the same position are used to estimate the shape of a crack.

DETAILED DESCRIPTION OF THE INVENTION

0001

TECHNICAL FIELD OF INVENTION

This invention relates to an ultrasonic flaw detecting method for pipe weld seams wherein vibration fatigue cracks and stress corrosion cracks, which occur from the inside surface around weld seams because of unevenness of the inside surface or tensile residual stress or metallurgical changes, are estimated from the outside in order to provide information to determine whether shipment is possible for a manufacturer or whether replacement is necessary for a user.

0002

PRIOR ART

It is known that when cracks which occur in pipes achieve a depth greater than 1/10 of the pipe thickness, the cracks grow rapidly in a time period shorter than the time spent to that point, and there is a possibility of penetrating through the pipe. Therefore, it is desirable to be able to detect relatively shallow cracks which have a depth less than approximately 1/10 of a pipe thickness.

0003

Ultrasonic flaw detection methods which make an incident ultrasonic wave and detect the reflected wave (echo) from a crack are currently mainstream for cracks on the inside surface of pipes. Specifically, as shown in Fig. 15 (a), an ultrasonic probe 1 is placed in a position where pipe 2 cracks 3 are highly probable, ultrasonic waves 4 are made incident on a spread of 20° ~ 30° (divergence angle), the change in acoustic pressure of the reflected waves 5 which are reflected by the crack 3 are converted to electronic signals as shown in Fig. 15 (b), and those peak values are measured. Next, the relationship between the depth of cracks which had already been confirmed and the peak values of the electronic signal are compared and the depth of a crack 3 in this position is estimated. Later, the position for this measurement is changed and repeated multiple times, and then the depth and spread of crack 3 are determined. Note, in Fig. 15, Flag 6 is the weld seam.

0004

PROBLEM TO BE RESOLVED BY INVENTION

However, with this type of conventional ultrasonic flaw detection means, a standard ultrasonic probe with an ultrasonic wave 4 divergence angle of 20° ~ 30° is used, but the acoustic pressure

obtained from shallow cracks 3 equal to approximately 1/10 of the pipe thickness or shallow cracks 3 less than 0.5 mm is small so distinguishing between signal and noise is difficult.

0005
Therefore, as shown in Fig. 16 (a), a focusing ultrasonic probe 7 with a narrow divergence angle of 5° ~ 10° is used, and the strong reflected acoustic pressure from a crack is also obtained, but because the field of detection is narrow, at distances equivalent to the pipe thickness, actual cracks 3, namely those which move nearer or farther from the weld line, so-called fluctuating cracks, are sometimes overlooked. Furthermore, because the divergence angle is narrow, there is a problem in obtaining stable reflected acoustic pressure from actual cracks 3 which have a zigzag shape and many uneven surfaces, and therefore use has been limited.

0006
Therefore, the purpose of this invention is to resolve the above problems and provide an ultrasonic flaw detecting method for pipe weld seams which can measure with high precision minute cracks which occur on the inside of a pipe.

0007
MEANS TO RESOLVE PROBLEMS
In order to resolve the above problems, the invention claimed in Claim 1 is an ultrasonic flaw detecting method for pipe weld seams which extend in the circumferential direction of a pipe where ultrasonic waves are made incident on the outside of the pipe, reflected waves from a crack are detected, and the crack measured while moving the position in the circumferential direction along the weld seam, characterized by determining the distance to a base point where an ultrasonic probe should be positioned with regards to a weld seam based on the location where a weld seam proximal crack is predicted and the angle of incidence of the ultrasonic wave, positioning a focusing ultrasonic probe which has a narrow ultrasonic wave divergence angle at a base position having said distance in the axial direction of the pipe from the weld seam of the pipe outer surface, scanning the whole circumference while moving said focusing ultrasonic probe in the circumferential direction by minute pitches of 1° ~ 5°, measuring three types of reflected waves, namely the reflected wave obtained by making an ultrasonic wave incident on the welded joint from the pipe axial direction, the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of 5° ~ 15° from the pipe axial direction, and the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of -5° ~ -15° from the pipe axial direction, and using the maximum value at one destination point of said three types of reflected waves to estimate the shape of a crack.

0008
By using the invention of Claim 1 constituted in this manner, high reflected acoustic pressure can be obtained from a crack by using a focusing ultrasonic probe, so the signal and noise can positively be distinguished, and minute cracks will be able to be detected.

0009
By moving the position of a focusing ultrasonic probe by a minute pitch of 1° ! 5° in the circumferential direction while scanning along the whole circumference, the whole circumference can be measured without a lapse.

0010

By using the maximum value from the three types of reflected waves, namely reflected waves when ultrasonic waves are made incident from the axial direction of the pipe, reflected waves when the ultrasonic waves are made incident with an inclination of $5° \sim 15°$ from the pipe axial direction, and reflected waves when the ultrasonic waves are made incident with an inclination of $-5° \sim -15°$ from the pipe axial direction, stable reflected acoustic pressure will be able to be obtained from actual cracks which have a zigzag form.

0011

Using the above, it is possible to positively and accurately measure minute cracks which occur on the inner surface of a pipe.

0012

The invention claimed in Claim 2 is an ultrasonic flaw detecting method for pipe weld seams which extend in the axial direction of a pipe where ultrasonic waves are made incident on the outside of the pipe, reflected waves from a crack are detected, and the crack measured while moving the position in the axial direction along the weld seam, characterized by determining the distance to a base point where an ultrasonic probe should be positioned with regards to a weld seam based on the location where a weld seam proximal crack is predicted and the angle of incidence of the ultrasonic wave, positioning a focusing ultrasonic probe which has a narrow ultrasonic wave divergence angle at a base position having said distance in the circumferential direction of the pipe from the weld seam of the pipe outer surface, scanning the whole length of the weld seam while moving said focusing ultrasonic probe in the axial direction by designated pitches, measuring three types of reflected waves, namely the reflected wave obtained by making an ultrasonic wave incident on the welded joint from the pipe circumferential direction, the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of $5° \sim 15°$ from the pipe circumferential direction, and the reflected wave obtained by making the ultrasonic wave incident on the welded joint with an inclination of $-5° \sim -15°$ from the pipe circumferential direction, and using the maximum value at one destination point of said three types of reflected waves to estimate the shape of a crack.

0013

By using the invention of Claim 2 constituted in this manner, high reflected acoustic pressure can be obtained from the crack by using a focusing ultrasonic probe, so the signal and noise can positively be distinguished, and minute cracks will be able to be detected.

0014

By moving the position of a focusing ultrasonic probe by a designated pitch in the axial direction of the pipe while scanning along the whole length of the weld seam, the whole weld seam can be measured without a lapse.

0015

By using the maximum value from the three types of reflected waves, namely reflected waves when ultrasonic waves are made incident from the circumferential direction, reflected waves when the ultrasonic waves are made incident with an inclination of $5° \sim 15°$ from the circumferential direction, and reflected waves when the ultrasonic waves are made incident with

an inclination of -5° ~ -15° from the circumferential direction, stable reflected acoustic pressure will be able to be obtained from actual cracks which have a zigzag form.

0016
Using the above, it is possible to positively and accurately measure minute cracks which occur on the inner surface of a pipe.

0017
With the invention claimed in Claim 3, the operations of said Claim 1 or Claim 2 are performed at a new base position 0.1 ~ 0.3 times the pipe thickness closer than said base position and at a new base position 0.1 ~ 0.3 times the pipe thickness farther than said base position, if necessary the operations of said Claim 1 or Claim 2 are also performed at a new base position 0.4 ~ 0.6 times the pipe thickness closer than said base position and at a new base position 0.4 ~ 0.6 times the pipe thickness farther than said base position, and the maximum values from the three types or five types of reflected waves obtained from the same position are used to estimate the shape of a crack.

0018
According to the invention of Claim 3 constituted in this manner, by changing the base position in the axial direction of the pipe and performing the operations of Claim 1 or Claim 2, measuring in the range equivalent to the pipe thickness will be possible. Therefore, actual cracks which move closer and farther from the weld line, so-called fluctuating cracks, can be measured without lapse.

0019
IMPLEMENTATION FORMS OF THE INVENTION
Specific implementation forms of this invention will be described with drawings.

0020
Fig. 1 through Fig. 5 show implementation forms of this invention. Note, descriptions of areas which are identical or equivalent with previously mentioned conventional examples will be omitted by applying identical flags.

0021
Ultrasonic flaw detecting devices for pipe weld seams which use this implementation form are equipped with a focusing ultrasonic probe 11 with a narrow angle of divergence for ultrasonic waves 4, a motion drive part, not shown in the drawings, for moving said focusing ultrasonic probe 11 along the weld seam 12, a moving part controller which controls said motion drive part, a rotating drive part which causes said focusing ultrasonic probe 11 to tilt with regards to the weld seam 12, a drive part controller which controls said rotating drive part, an acoustic pressure signal peak value A/D converter which determines the maximum value of the reflected waves 5, a recorder which records the acoustic pressure signal of the reflected waves 5 and the inclination angle 13 of the focusing ultrasonic probe 11, a plotter which plots the acoustic pressure signal of the reflected waves 5 and the inclination angle 13 of the focusing ultrasonic probe 11, and various control panels or the like.

0022
Furthermore, with regards to a weld seam which extends in the circumferential direction 33 of pipe 2, when ultrasonic waves 4 are made incident on the outside surface of pipe 2 while moving position in the circumferential direction 33 along a weld seam 12, the distance 15 to the base position 14 where the ultrasonic probe 1 should be placed for weld seam 12 is determined based on the estimated position of a crack 3 proximal to the weld seam 12 and the angle of incidence of the ultrasonic wave 4, as shown in Fig. 2 (a).

0023
Next, the focusing ultrasonic probe 11 which has a narrow angle of divergence for ultrasonic waves 4 is positioned at a base position 14 which is said distance 15 in the axial direction of the pipe away from the weld seam 12 of the outer surface of the pipe 2, and said focusing ultrasonic probe 11 is made to scan along the whole circumference while moving position by minute pitches of 1° ~ 5° in the circumferential direction 33.

0024
Also, as shown in Fig. 1 (b), ultrasonic waves 4 are made incident from the axial direction 16 of the pipe (orthogonal direction to the weld seam 12) with regards to the weld seam 12, and reflected waves 5 are obtained. Furthermore, as shown in Fig. 1 (c), ultrasonic waves 4 are made incident from an incline of 5° ~ 15° from the axial direction 16 of the pipe with regards to the weld seam 12, and reflected waves 5 are obtained. Moreover, as shown in Fig. 1 (d), ultrasonic waves 4 are made incident from an incline of -5° ~ -15° from the axial direction 16 of the pipe with regards to the weld seam 12, and reflected waves 5 are obtained. Therefore, the above three types of reflected waves 5 are measured from nearly the same destination point.

0025
In this case, it is also acceptable to perform all three operations, namely making ultrasonic waves 4 incident from the axial direction 16 of the pipe, making ultrasonic waves 4 incident from an incline of 5° ~ 15° from the axial direction 16 of the pipe, and making ultrasonic waves to incident from an incline of -5° ~ -15° from the axial direction 16 of the pipe, from one location before causing the focusing ultrasonic probe 11 to scan in the circumferential direction 33.

0026
Alternatively, it is also acceptable to scan with the focusing ultrasonic probe 11 in the circumferential direction 33 while making ultrasonic waves 4 incident from the axial direction 16 of the pipe, and then scan with the focusing ultrasonic probe 11 in the circumferential direction 33 while making ultrasonic waves 4 incident 5° ~ 15° from the axial direction 16 of the pipe, and finally scanning with the focusing ultrasonic probe 11 in the circumferential direction 33 while making ultrasonic waves 4 incident -5° ~ -15° from the axial direction 16 of the pipe.

0027
Note, the position of the focusing ultrasonic probe 11 when the focusing ultrasonic probe 11 is at an angle is adjusted to the destination point of the ultrasonic waves 4 caused by the inclination of the focusing ultrasonic probe 11.

0028
However, if the inclination angle 13 of the focusing ultrasonic probe 11 is small, or if the angle of incidence of the focusing ultrasonic probe 11 is less than 45°, the difference between the destination position of the ultrasonic waves 4 caused by the inclination of the focusing ultrasonic probe 11 and the position of the focusing ultrasonic probe 11 will be minimal, so the operation of correcting the position may be omitted. Furthermore, when detecting for relatively deep cracks 3, the permissible range of measuring error of the length of the crack 3 is large, so the operation of correcting the position may be omitted.

0029
Finally, as shown in Fig. 1 (e), the maximum value of said three types of reflected waves 5 from nearly the same destination point is used, and the shape of the crack 3 is estimated by plotting the relationship between the crack 3 and the position.

0030
Furthermore, in addition to the above, each of the above operations is performed at new base positions which are at a position 17 which is at a distance of 0.1 ~ 0.3 times the pipe thickness closer to the weld seam 12 than the original base position 14, and a position 18 which is at a distance of 0.1 ~ 0.3 times the pipe thickness farther from the weld seam 12 than the original base position 14.

0031
Furthermore, if necessary, each of the above operations is performed at new base positions which are at a position 19 which is at a distance of 0.4 ~ 0.6 times the pipe thickness closer to the weld seam 12 than the original base position 14, and a position 20 which is at a distance of 0.4 ~ 0.6 times the pipe thickness farther from the weld seam 12 than the original base position 14.

0032
Furthermore, the maximum value from the three types or five types of reflected waves 5 obtained from the same position are used to estimate the shape of the crack 3.

0033
Next, the function of this implementation form will be described.

0034
As shown in Fig. 1 and Fig. 2, the ultrasonic probe device for weld seams 12 of pipes has a focusing ultrasonic probe 11 which makes ultrasonic waves 4 with a narrow divergence angle incident on the pipe 2, and receives reflected waves 5 from cracks 3 which occur proximal to the weld seam 12. The focusing ultrasonic probe 11 has a beam spread which is nearly fixed, and a directivity of approximately ± 10° as shown in Fig. 3. The moving part controller sends a control signal to the drive part for motion, and causes the focusing ultrasonic probe 11 to move a desired pitch along the weld seam 12. The drive part controller sends a control signal to the rotation drive part and causes the focusing ultrasonic probe to incline.

0035
Also, the acoustic pressure signal peak value A/D converter determines the maximum value of the reflected waves 5 for a single position. Furthermore, the recorder reports the acoustic pressure signal and the inclination angle 13 of the focusing ultrasonic probe 11, and the plotter plots this information.

0036
High reflected acoustic pressure can be obtained from cracks 3 by using a focusing ultrasonic probe 11 in this manner, so the signal and noise can positively be distinguished and minute cracks 3 will be able to be detected.

0037
By scanning the whole circumference while moving the position of the focusing ultrasonic probe 11 by minute pitches of 1° ~ 5° in the circumferential direction 33, the whole circumference will be able to be measured without lapse.

0038
By using the maximum value of the three types of reflected waves 5, namely the reflected waves 5 when ultrasonic waves 4 are incident from the axial direction 16 of the pipe, the reflected waves 5 when ultrasonic waves 4 are incident at an angle of 5° ~ 15° from the axial direction 16 of the pipe, and the reflected waves 5 when ultrasonic waves 4 are incident at an angle of -5° ~ -15° from the axial direction 16 of the pipe, stable reflected acoustic pressure will be able to be obtained from actual cracks 3 which have multiple uneven surfaces and a zigzag configuration.

0039
In other words, as shown in Fig. 1, actual cracks 3 are aggregations of small planes 21 ~ 23 with a diameter of 1 mm ~ 5 mm, and approximately half are inclined more than 10° from the weld seam 12, but most have an inclination less than 20°, so by making the ultrasonic waves 4 incident at an angle of ± 5° ~ ± 15° from the axial direction 16 of the pipe, most of the cracks 3 will be able to be measured. Note, as shown in Fig. 4, sufficient reflective acoustic pressure cannot be obtained from cracks 3 which have an inclination greater than 10° if the ultrasonic waves 4 are only made incident without an inclination.

0040
Therefore, minute cracks 3 which occur at the inner surface of a pipe 2 will be able to be positively and accurately measured.

0041
Furthermore, by changing the base position 14 by ± 0.1 ~ ± 0.3 times the pipe thickness or by ± 0.4 ~ ± 0.6 times the pipe thickness in the axial direction 16 of the pipe and then performing the above operations, measurements will be able to be made in a range equivalent to the pipe thickness. Therefore, as shown in Fig. 5, actual cracks 3 which get closer and farther away from the weld line (weld seam 12), with a so-called fluctuating position ($a \neq b \neq c \neq d$) which are dependent on variation in the axial direction of weak points in the weld, will be able to be measured without lapse. Note, weak points in the weld include areas where the melting of the taper was insufficient, protrusions of the weld stop end, and areas of altered properties caused by

being held for a long period of time in a temperature range of 400°C ~ 600°C during welding.

0042
Note, another implementation form of this invention can be applied for weld seams 12 which extend in the axial direction 16 of the pipe 2, by moving position in the axial direction 16 of the pipe along the weld seam 12 while making ultrasonic waves 4 incident from the outside surface of the pipe 2, detecting the reflected waves 5 from a crack 3, and measuring the crack 3.

0043
In this case, the distance 15 to the base position 14 where the ultrasonic probe 1 is to be placed for weld seam 12 is determined based on the estimated position of cracks proximal to the weld seam 12 and the incident angle of the ultrasonic waves 4, the focusing ultrasonic probe 11 which has a narrow angle of divergence for ultrasonic waves 4 is positioned at a base position 14 which has the above distance 15 in the circumferential direction 33 from the weld seam 12 of the outer surface of the pipe 2, said focusing ultrasonic probe 11 is moved a small incremental pitch such as 1 mm ~ 2 mm in the axial direction 16 of the pipe while scanning along the whole length of the weld seam 12, the maximum value from nearly the same destination position of the abovementioned three types of reflected waves 5, namely the reflected waves 5 when ultrasonic waves 4 are incident from the circumferential direction 33 of the weld seam 12, the reflected waves 5 when ultrasonic waves 4 are incident at an angle of 5° ~ 15° from the circumferential direction 33 of the weld seam 12, and the reflected waves 5 when ultrasonic waves 4 are incident at an angle of -5° ~ -15° from the circumferential direction 33 of the weld seam 12, are used, and the relationship between the cracks 3 and the position are plotted in order to estimate the shape of the cracks 3.

0044
In this manner, even when applied to weld seams 12 which extend in the axial direction of a pipe 2, high reflected acoustic pressure from cracks 3 can be obtained by using a focusing ultrasonic probe 11, so signal and noise can be positively distinguished and minute cracks 3 will be able to be detected.

0045
By moving the position of the focusing ultrasonic probe 11 by minute pitches in the axial direction of the pipe while scanning along the whole length of the weld seam 12, the whole length of the weld seam 12 will be able to be measured without lapse.

0046
By using the maximum value of the three types of reflected waves 5, namely the reflected waves 5 when ultrasonic waves 4 are incident from the circumferential direction 33 of the weld seam 12, the reflected waves 5 when ultrasonic waves 4 are incident at an angle of 5° ~ 15° from the circumferential direction 33 of the weld seam 12, and the reflected waves 5 when ultrasonic waves 4 are incident at an angle of -5° ~ -15° from the circumferential direction 33 of the weld seam 12, stable reflected acoustic pressure will be able to be obtained from actual cracks which have a zigzag shape.

0047
Therefore, minute cracks 3 which occur on the inner surface of a pipe 2 will be able to be positively and accurately measured.

0048
PREFERRED EMBODIMENTS
Preferred embodiments of This invention will be described below.

Preferred Embodiment 1
Artificial flaws in the form of slits with depths of 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm, 2.5 mm, and 3.0 mm and a width of 0.5 mm were established on the inside surface of a pipe 2 which withstands pressure of 160 kilo and has a callout diameter of 20 mm, a focusing ultrasonic probe 11 with an incident angle of 70°, a focal diameter of 2 mm, and a focal length in the depth direction of 2 mm ~ 8mm was pressed to contact and moved in 1° increments around the circumference of a pipe 2, ultrasonic waves 4 were transmitted and received from said slits, and the peak values of the acoustic pressure signals of the reflected waves 5 were recorded.

0049
As shown in Fig. 6, the results confirmed that noise was at several percent and that a slit with a depth of 0.5 mm could clearly be detected.

0050
On the other hand, a standard ultrasonic probe 1 with a wide angle of divergence was used as a comparison example, and as shown in Fig. 7, noise was observed to have a height of 20% on the CRT screens of the dB display, and it was confirmed that a slit with a depth of 0.5 mm was buried in the noise and could not be detected.

Preferred Embodiment 2
A weld seam 12 was created between a stainless steel pipe which had a callout diameter of 20 mm and could withstand pressure of 160 kilos and a socket, and this unit was immersed for 1.5 hours in a boiling aqueous solution of magnesium chloride with a concentration of 42%. The focusing ultrasonic probe 11 used in Preferred Embodiment 1 was used to scan this pipe 2 with the parameters of an inclination angle 13 for the focusing ultrasonic probe 11 of ± 10° and a movement interval (angle) of 10° in the circumferential direction 33.

0051
As shown in Fig. 8, the results showed that relatively strong reflected waves 5 were obtained between the positions at circumferential angles 10° ~ 100°. The maximum depth of the cracks 3 was 2.0 mm (2 mm equivalent to level of 100%) and the length of the stress corrosion crack 3 was 75° by angular expression. As shown in Fig. 9, this was nearly equal to the depth of the crack 3 obtained by cutting the pipe 2 and observing under a microscope. On the other hand, as shown in Fig. 10, when the focusing ultrasonic probe 11 is used without inclining, sufficient reflective acoustic pressure could not be obtained and cracks 3 could not be detected in positions 60° and 80°.

Preferred Embodiment 3

A weld seam 12 was created between a stainless steel pipe which had a callout diameter of 20 mm and could withstand pressure of 160 kilos and a socket, and this unit was immersed for 1.0 hours in a boiling aqueous solution of magnesium chloride with a concentration of 42%. The focusing ultrasonic probe 11 used in Preferred Embodiment 1 was used to scan this pipe 2 with the parameters of an inclination angle 13 for the focusing ultrasonic probe 11 of ± 10° and a movement interval (angle) of 1° in the circumferential direction 33.

0052

As shown in Fig. 11, reflected waves 5 which were twice the level of noise were obtained at a position across the circumferential angle of 270° ~ 360°. The maximum depth of the crack 3 was determined to be 0.6 mm (2 millimeters equivalent to level of 100%) by using a calibration chart. This value was relatively close to the crack depth of 0.25 mm obtained by cutting the pipe 2 and observing under a microscope as shown in Fig. 12.

0053

On the other hand, as a comparison example, when measurements were performed without inclining the focusing ultrasonic probe 11, there was just a hint of a crack 3 as shown in Fig. 13, and when a standard ultrasonic probe 1 with a wide divergence angle was used, it was buried in the noise as shown in Fig. 14.

0054

EFFECT OF THE INVENTION

As described above, according to the invention of Claim 1, high reflected acoustic pressure from cracks can be obtained by using a focusing ultrasonic probe, so the signal and noise can positively be distinguished and minute cracks are able to be detected.

0055

By moving the focusing ultrasonic probe by minute pitch increments of 1° ~ 5° in the circumferential direction, and scanning along the whole circumference, the whole circumference will be able to be measured without lapse.

0056

By using the maximum value from three types of reflected waves, namely the reflected waves when ultrasonic waves are incident from the axial direction of the pipe, the reflected waves when ultrasonic waves are incident at an angle of 5° ~ 15° from the axial direction of the pipe, and the reflected waves when ultrasonic waves are incident at an angle of -5° ~ -15° from the axial direction of the pipe, stable reflected acoustic pressure from actual cracks which have a zigzag shape will be able to be obtained.

0057

Therefore, minute cracks which occur on the inner surface of a pipe will be able to be positively and accurately measured.

0058

According to the invention of Claim 2, high reflected acoustic pressure from cracks can be

obtained by using a focusing ultrasonic probe, so the signal and noise can positively be distinguished and minute cracks are able to be detected.

0059
By moving the focusing ultrasonic probe by a desired pitch in the axial direction of the pipe and scanning along the whole length of the weld seam, the whole length of the weld seam will be able to be measured without lapse.

0060
By using the maximum value from three types of reflected waves, namely the reflected waves when ultrasonic waves are incident from the circumferential direction, the reflected waves when ultrasonic waves are incident at an angle of 5° ~ 15° from the circumferential direction, and the reflected waves when ultrasonic waves are incident at an angle of -5° ~ -15° from the circumferential direction, stable reflected acoustic pressure from actual cracks which have a zigzag shape will be able to be obtained.

0061
Therefore, minute cracks which occur on the inner surface of a pipe will be able to be positively and accurately measured.

0062
According to the invention of Claim 3, by changing the base position toward the axial direction of the pipe and performing the operations of said Claim 1 or Claim 2, measurements can be made for a range equivalent to the pipe thickness. Therefore, actual cracks which move closer and farther away from the weld line, with a so-called fluctuating position, will be able to be measured without lapse, thus showing practical and beneficial effects.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 (a) ~ (e) are drawings which show a detection method using a focusing ultrasonic probe which is an implementation form of this invention.

Fig. 2 (a) is a partial expanded side view cross-section drawing showing the condition when a pipe weld seam crack is measured using a focusing ultrasonic probe which is a implementation form of this invention, and Fig. 2 (b) is a graph showing the waveform of the ultrasonic waves and reflected waves of (a).

Fig. 3 is a graph showing the directivity of a focusing ultrasonic probe.

Fig. 4 (a) (b) are drawings similar to those of Fig. 1 for the case where the focusing ultrasonic probe was not inclining for a comparison example.

Fig. 5 is a perspective view drawing showing the fluctuating position of a crack proximal to the weld seam.

Fig. 6 is a graph showing the reflected waves from a slit type artificial flaw for Preferred

Embodiment 1.

Fig. 7 is a graph showing the reflected waves from a slit type artificial flaw for the comparison example of Preferred Embodiment 1.

Fig. 8 is a graph showing the reflected waves from a typical stress corrosion crack for Preferred Embodiment 2.

Fig. 9 is a graph showing the shape of a microscope observation of a typical stress corrosion crack.

Fig. 10 is a graph showing the reflected waves from a typical stress corrosion crack for the comparison example of Preferred Embodiment 2.

Fig. 11 is a graph showing the reflected waves from a minute stress corrosion crack for Preferred Embodiment 3.

Fig. 12 is a graph showing the shape of a microscope observation of a minute stress corrosion crack.

Fig. 13 is a graph showing the reflected waves from a minute stress corrosion crack when the focusing ultrasonic probe is not inclined for the comparison example of Preferred Embodiment 3.

Fig. 14 is a graph showing the reflected waves from a minute stress corrosion crack using a typical ultrasonic probe as a comparison example for Preferred Embodiment 3.

Fig. 15 (a) is a partial expanded side view cross-section drawing of the conventional example showing the condition of measuring a crack at the weld seam of a pipe using a typical ultrasonic probe, and Fig. 15 (b) is a graph showing the waveform of the ultrasonic waves and the reflected waves.

Fig. 16 (a) is a partial expanded side view cross-section drawing of the conventional example showing the condition of measuring a crack at the weld seam of the pipe using a focusing ultrasonic probe, and Fig. 16 (b) is a graph showing the waveform of the ultrasonic waves and the reflected waves.

DESCRIPTION OF FLAGS

2	pipe
3	crack
4	ultrasonic waves
5	reflected waves
11	focusing ultrasonic probe
12	weld seam
13	inclination angle
14	base position
15	distance
16	axial direction of pipe
17	position

18 position
19 position
20 position
33 circumferential direction

Figure 1

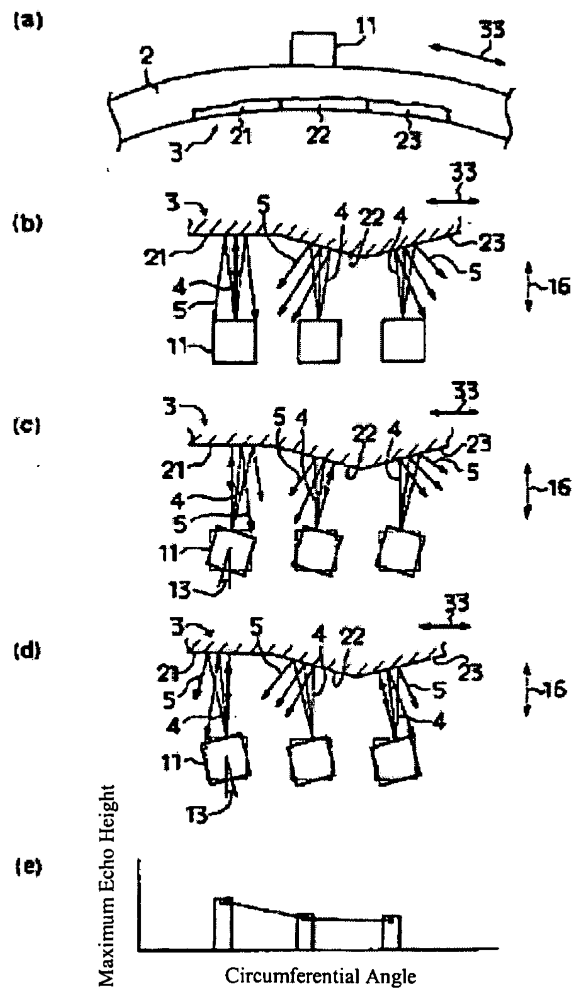


Figure 2

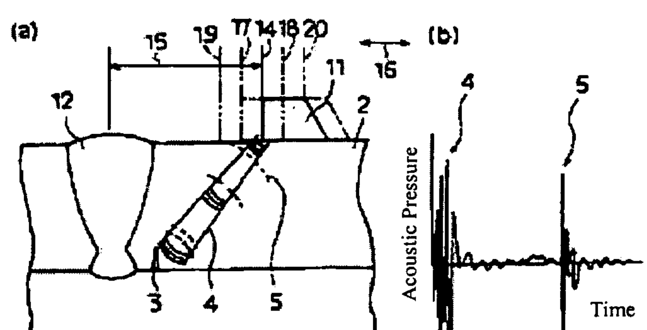
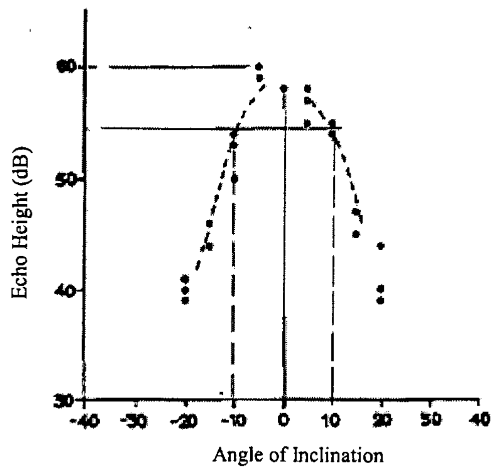


Figure 3



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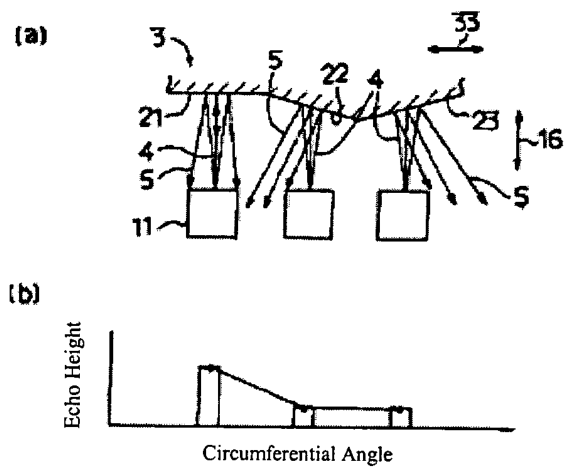

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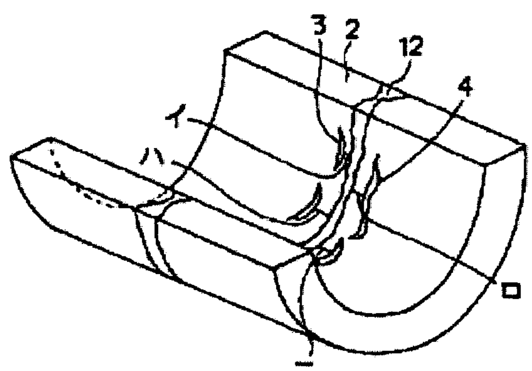

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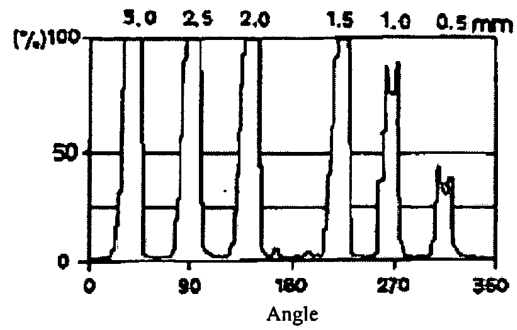

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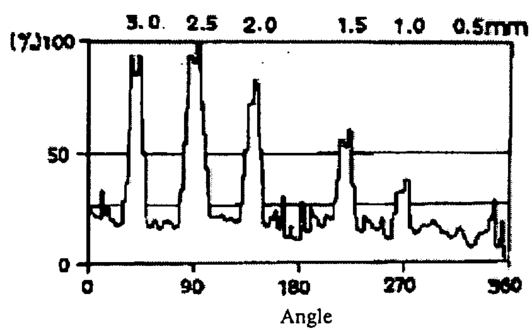

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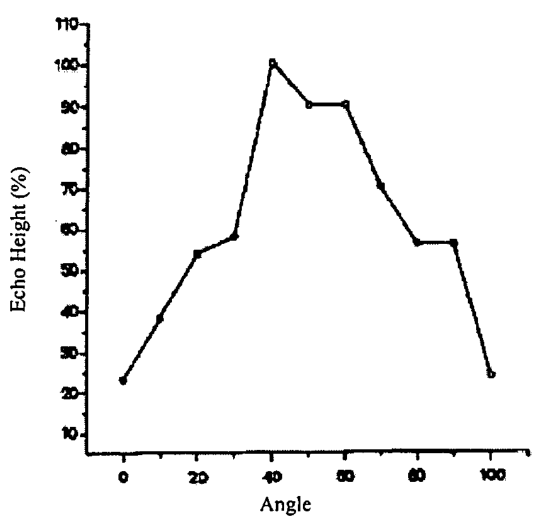

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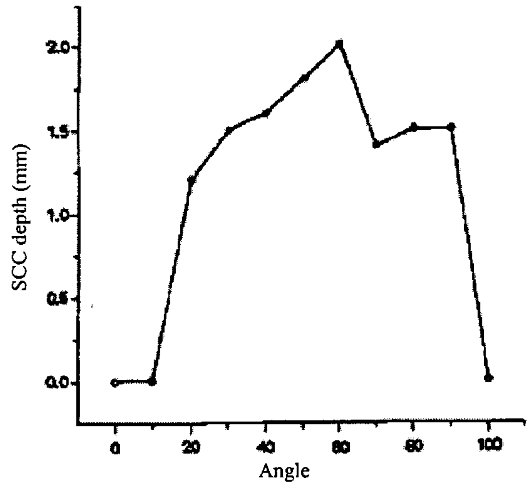

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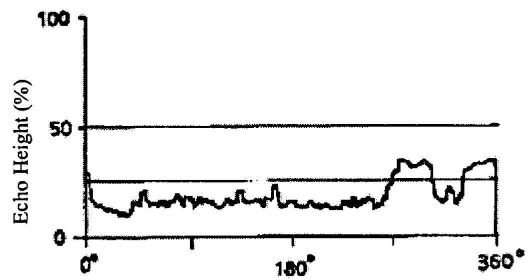
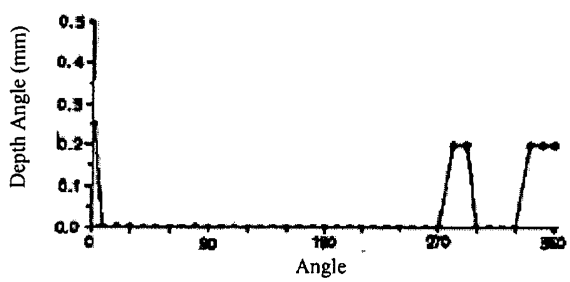


Figure 12



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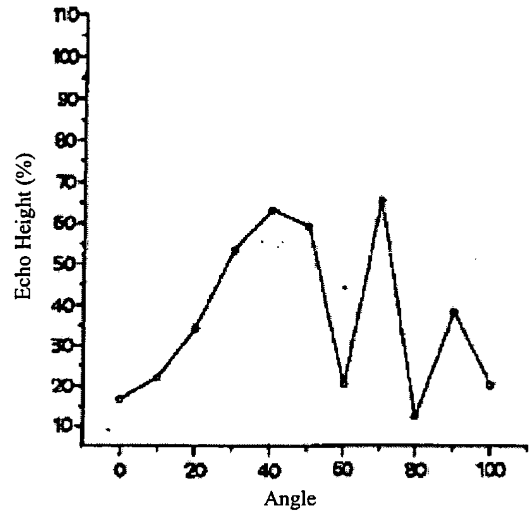

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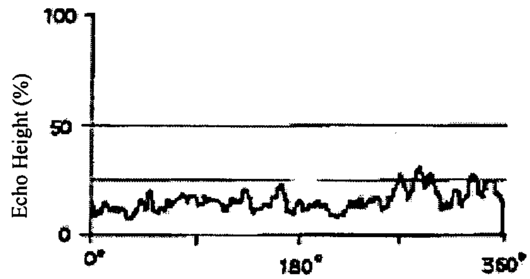

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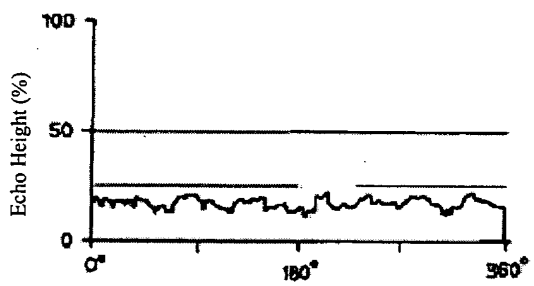


Figure 15

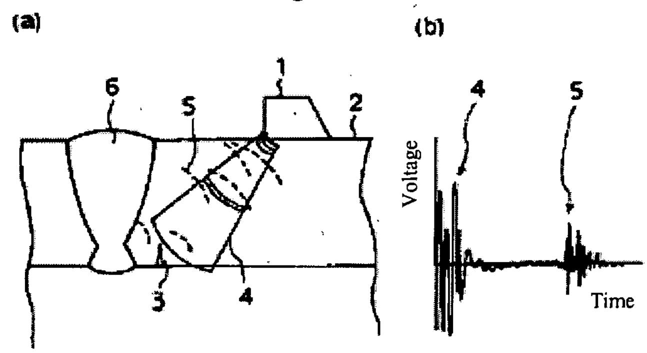
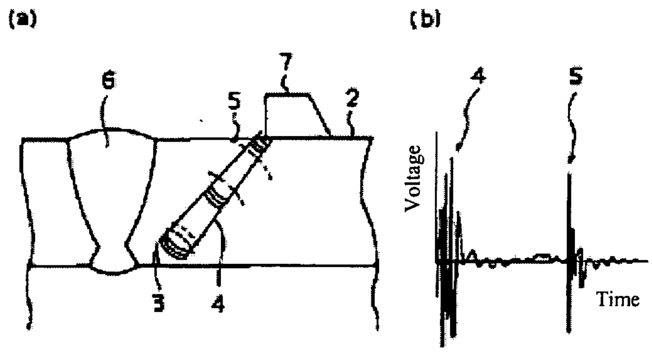


Figure 16



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F Term (Reference)

2G047 AA07 AB01 AB07 BA03 BB02
BC07 BC10 BC11 DB17 EA10
EA11 GB24 GF31 GG09 GG24